

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



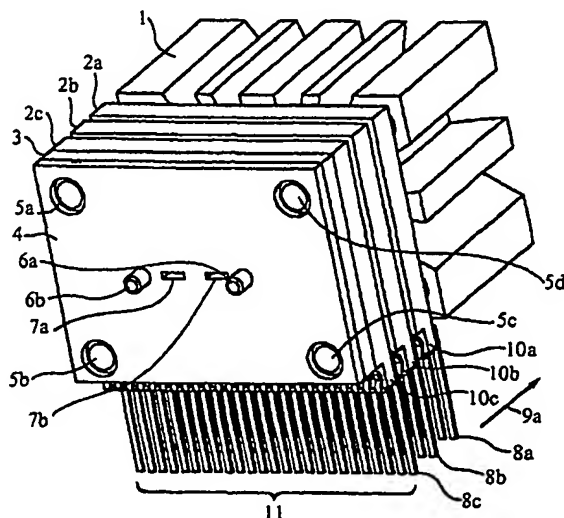
(43) International Publication Date
14 June 2001 (14.06.2001)

PCT

(10) International Publication Number
WO 01/42801 A1

- (51) International Patent Classification⁷: G01R 31/02, H04B 10/02, 10/00, H02B 1/00, H05K 7/20, G02B 6/36, H01L 29/788, 33/00
- (72) Inventors: YUEN, Albert, T.; 463 Los Pajaros Court, Los Altos, CA 94024 (US). MERTZ, Pierre, H.; 1700 California Street, Apartment 2, Mountain View, CA 94041 (US).
- (21) International Application Number: PCT/US00/28017
- (74) Agent: ALBOSZTA, Marek; 45 Cabot Avenue, Suite 110, Santa Clara, CA 95051-6670 (US).
- (22) International Filing Date: 10 October 2000 (10.10.2000)
- (81) Designated States (national): CA, CN, JP.
- (25) Filing Language: English
- (84) Designated States (regional): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
- (26) Publication Language: English
- (30) Priority Data:
09/459,422 9 December 1999 (09.12.1999) US
- Published:
— With international search report.
- (71) Applicant: ALVESTA, INC. [—/US]; 495 Mercury Drive, Sunnyvale, CA 94085-4707 (US).
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR COMBINED ALIGNMENT AND HEAT DRAIN OF STACKED PROCESSING STAGES



(57) Abstract: A method and apparatus for cooling and simultaneously aligning processing devices consisting of stacked processing stages (PS). The invention utilizes heat drain profiles (5a-d) that are held in position and parallel orientation by a heat sink base (1). The heat drain profiles (5a-d) protrude through soldering holes (14) of each processing stage. The soldering holes (14) have a heat bridge characteristic (HTC) defined mainly by their surface material, their surface area, and their fitting precision. The heat drain profiles (5a-d) are of number, size and material such that they drain a minimal thermal energy at the lowest temperature difference between heat sink base (1) and PS for a given HTC. The minimal thermal energy is higher than the maximum thermal energy created within a PS.



WO 01/42801 A1

5

Patent Application of

10

For**Method and Apparatus for Combined Alignment and Heat Drain
of Stacked Processing Stages**

15

Field of Invention

20 The present invention relates to a method and an apparatus
for combined alignment and heat drain of stacked processing
stages and in particular to a method and apparatus for
combined alignment and heat drain of individual modules of
an optical multiplex transceiver.

25

Background of the Invention

30 The demand for speed of signal processing in a computer and
for capacity in signal communication between several
computers is ever increasing. A technique to meet the

demand for high signal transmission is optical multiplexing such as wavelength division multiplexing (WDM) and time division multiplexing (TDM). In the WDM technique, the spectrum of a light beam transmitted in an optical fiber is
5 divided into a number of wavelength divisions, which represent independent signal strings for transmitting information. Each wavelength division is an independent signal carrier. Hence, the advantage of optical multiplexing is its ability to transmit simultaneously in a
10 single optical fiber a high number of information.

In a number of optoelectronic processing stages (OPS) optical signals of distinct wavelength are either collinear emitted or collinear received. These OPS are typically
15 monolithically grown structures with a planar bottom and top surface. The optical signals are emitted or received perpendicular to the planar top surface.

US. Pat. No. 5,487,124 discloses a bi-directional
20 wavelength division multiplex transceiver module, wherein a semi-translucent mirror is used to separate wavelength division multiplexed signals and redirect them to individual OPS's.

25 Recent research achievements allow the fabrication of semi-translucent OPS's with distinct translucent/opaque properties such that they work simultaneously as an optical bandwidth filter and an optoelectronic converter. These OPS's are made opaque only for the spectrum of their
30 predetermined wavelength division and are sufficiently

translucent for the remaining light spectrum. In case of a receiver, a number of stacked OPS's with distinct absorption spectra are sequentially arranged and absorb the wavelength divisions of a through passing light beam. In case of an emitter each OPS adds its signal in the distinct wavelength division to the passing light beam. As a result, the effort of multiplex transceivers to combine/separate the individual wavelength divisions and direct them from/to the corresponding OPS is significantly reduced such that the number of OPS in a single multiplex transceiver can be increased.

Optical multiplex systems are superior to electrical transmission systems, because they are noise free and enable a much longer transmission distance. These advantages are not only utilized for communication between computers or individual circuit boards but also within a stacked multichip circuit.

US. Pat. No. 5,568,574 discloses modulator-based photonic chip-to-chip interconnections for dense three-dimensional multichip module integration. In this invention, a number of OPS's are embedded within individually manufactured semiconductor structures that perform logical operations and are placed in tightly stacked processing stages (PS) above each other. The OPS's are placed in corresponding alignment in each of the semiconductor structures such that the optical signal beams travel vertically through the semiconductor stack. Thus, circuit boards with their two-

dimensional conductive connections between the individual chips are replaced by a three-dimensional structure.

5 Semi-translucent OPS open up new possibilities for highly compact, tightly stacked PS. The high processing capacity in such PS produces heat. In conventional two-dimensional arrayed circuits and optoelectronic devices heat dissipation is relatively simple to achieve, since sufficient air contact surface is available for heat
10 exchange. A heat absorbing air stream is thereby either thermally stimulated or provided by a fan.

US. Pat. No. 5,280,191 discloses a packaging for pairs of optical devices having thermal dissipation means. The
15 invention discloses a design of a duplex transceiver with secondary circuitry and a heat sink for cooling. The heat sink is a sheet metal part, which provides flat areas with low thermal convection.

20 US. Pat. No. 5,513,073 discloses an optical device heat spreader and thermal isolation apparatus. In this invention of a duplex transceiver, the optoelectronic devices are connected to a heat spreader card, which is thermally isolated from the transceiver board. The heat
25 spreading card is a flat sheet metal piece kept in a insulating distance to the transceiver board.

In tightly stacked PS the ratio between air contact surface and generated heat decreases unfavorably. In addition to
30 that, alignment features surrounding the central circuitry

interrupt the heat flow to the remaining air contact surfaces at the sides of the PS.

US. Pat. No. 4,985,805 discloses a device for the cooling
5 of optoelectronic components and a flange joint used therefor. A number of processing stages are stacked above a heat drain base plate. The vertical alignment and heat drain from the processing stages to the base plate is accomplished by vertical metal plates that are laterally
10 attached to the processing stages with screws. The vertical metal plates have no designated alignment features, such that the achievable precision is not sufficient for stacked multiplexing PS. The metal plates have a certain elasticity such that the screw attachment
15 does not provide sufficient contact over the lengths and widths of the PS. Because of their bulkiness, screw connections are generally unfavorable for microelectronic assemblies.

20 Therefore, there exists a need for a method and apparatus to align a number of processing stages and simultaneously drain their processing heat. The current invention addresses this problem.

25 High capacity electrical circuitry is generally very sensitive to electromagnetic fields. Therefore, there exists a need for stacked processing stages to shield them against peripheral electromagnetic fields. The current invention addresses this need.

30

Typically, solid leads and solder pins are used to provide solid electrical ground. In stacked processing stages the available area is limited. Therefore, there exists a need to utilized existing features for a stable electrical
5 ground. The current invention addresses this need.

Objects and Advantages

10 Accordingly, it is a primary object of the present invention to provide a method and apparatus to simultaneously align a number of tightly stacked processing stages, drain their processing heat and keep them below a predetermined temperature.

15

It is a further object of the present invention to provide a stable voltage ground for stacked processing stages.

It is a further object of the present invention to provide
20 a faraday shield for stacked processing stages.

Summary of the Invention

25 The invention achieves alignment and simultaneous cooling of stacked processing stages (PS) with a number of parallel heat drain profiles (HDP) that protrude through soldering holes of each PS establishing mechanical and thermal connections. The contour lengths and the heights of the
30 soldering holes define bridging areas between PS and HDP.

The HDP's are held in position within a heat sink base, which is typically placed on one end of the PS stack. The heat sink base has ribs to increase its air contact surface. The alignment profiles are made of a thermally conductive material like for instance aluminum or copper based alloys.

Each PS has a central processing area (CPA) where the optoelectronic and electronic circuitry is placed. A surrounding ring structure (SRS) captures the radially travelling thermal energy that is produced in the CPA and drains it in the bridging areas to the HDP. The draining capacity is directly proportional to the size of the bridging area, the average temperature difference between the PS's and the HDP's at the bridging area and the quality of the snug fit.

The HDP's are placed in sufficient proximity on the SRS to drain the captured thermal energy such that the temperature difference within the SRS and subsequently within the CPA remains within a predetermined temperature range. The thermal energy travels inside the HDP towards the heat sink base where it is dissipated into the surrounding atmosphere.

Thermal energy flows from a thermal source with a high temperature level to a thermal drain with a low temperature level resulting in a temperature gradient along the thermal path. Materials with good thermal conductivity like

aluminum and copper are a first factor for helping to obtain the flat temperature gradients. The second factor is the size of the section area of the thermal path, which affects directly the slope of the temperature gradient for
5 a given thermal energy flow. In the current invention, each processing stage drains a certain thermal energy at a maximum allowable temperature to the HDP's, raising its temperature level and adding a step in the temperature gradient. The HDP has to have a minimum section area such
10 that the average temperature in the HDP at the most distant PS remains sufficiently below the PS temperature such that enough thermal energy can bridge over.

The preferred application of the invention is an optical
15 multiplex transceiver mainly consisting of several optoelectronic PS's (OPS's). The HDP's are arranged along the direction of the signal light beam. The heat sink base is typically an extrusion profile with cooling ribs and straight holes where the HDP's are soldered in. It is
20 positioned preferably opposite of the cable connecting side. The HDP's have a preferably circular contour, which allows a high fabrication precision with relatively little machining effort. The OPS are stacked next to the heat sink base leaving a certain gap for air circulation. A
25 number of functional stages are placed between the OPS or at the end of the stack as they are known for optical transceiver devices.

Solder ball connections are arrayed on the OPS to provide
30 electrical signal transmission between them.

Each OPS may have on a side an array of laterally extending solder pins that connect the multiplex transceiver mechanically and electrical with a printed circuit board.

5 The solder pins are preferably surface mount an edge of the OPS. The connection with the printed circuit board is optionally provided by edge castellations as they are known to those skilled in the art. The heat sink remains thermally insulated within a certain insulating distance to

10 the printed circuitry board.

The HDP's provide an electrical ground for the OPS by connecting them to the heat sink. The circular arrangement of the HDP's provides thereby a favorable faradic shield

15 effect against peripheral electromagnetic noise.

Brief Description of the Figures

20 **Fig. 1** shows a first perspective view of the preferred embodiment of the invention with the adapter side of the multiplex transceiver being visible.

Fig. 2 shows a second perspective view of the preferred

25 embodiment of the invention with the heat sink side of the multiplex transceiver being visible.

Fig. 3 shows a side view of the preferred embodiment of the invention and a corresponding graph visualizing the

30 temperature distribution in the heat drain profiles.

Fig. 4 shows a front view of an example of a single optoelectronic processing stage with superimposed isothermal curves.

5

Detailed Description

Although the following detailed description contains many
5 specifics for the purposes of illustration, anyone of
ordinary skill in the art will appreciate that many
variations and alterations to the following details are
within the scope of the invention. Accordingly, the
following preferred embodiment of the invention is set
10 forth without any loss of generality to, and without
imposing limitations upon, the claimed invention.

The invention performs four main tasks: first to align the
processing stages; second to drain sufficient thermal
15 energy from the processing stages; third to keep the stage
peak temperature sufficiently below a critical level for a
most unfavorable surrounding air temperature and hampering
influences like dust on the heat sink; and fourth to
provide a stable electrical ground to all stages. In the
20 following, the four main tasks are described in detail.

Fig. 1 shows a perspective view of a preferred application
of the invention for an optical multiplex transceiver. It
is appreciated that the method and apparatus of the
25 invention may be applied to any processing device, which at
least partially consists out of stacked processing stages
as they are known to those skilled in the art.

An exemplary number of processing stages **2a**, **2b**, **2c** are
30 stacked together with a first functional stage **3** and a

second functional stage 4 on the heat drain profiles 5a-d. The heat drain profiles 5a-d drain the heat created during the functional operation of the processing stages 2a, 2b, 2c in the heat drain direction 9a into a heat sink base 1.

5 Each of the processing stages 2a, 2b, 2c has a solder pin array 8a, 8b, 8c, which consist of surface mounted solder pins that extend laterally from socket shoulders 10a, 10b, 10c as it is known to those skilled in the art. The solder pin arrays 8a, 8b, 8c form a solder pin matrix 11, which

10 provides a two dimensional mechanical connection and a number of electrical contacts in a final assembly position on a printed circuit board (not shown). It is appreciated that the solder pins may be edge castellations as they are known to those skilled in the art. The solder pin arrays

15 8a, 8b, 8c may also drain some heat.

The heat drain profiles 5a-d are pressed into base holes 12a-d (see Fig. 2) of the heat sink base 1. The heat sink base 1 is preferably an extruded profile made of aluminum

20 or copper based material with an extrusion direction parallel to the main heat drain direction 9a. Design features of extruded fabricated profiles are generally parallel, which allows a precise alignment of the heat drain profiles 5a-d. In an optional reaming operation the

25 precision of the dimension and parallel orientation of the base holes 12a-d can be additionally increased.

The heat drain profiles 5a-d are made of a core material with a high thermal conductivity and have a preferably

30 circular section, which allows them to be manufactured with

the requisite precision. The core material is preferably an aluminum based material or a copper based material. Optional surface coatings like for instance gold or silver coating prevent oxidation and raise the thermal contact conductivity of the heat drain profiles 5a, 5b, 5c, 5d.

The processing stages 2a, 2b, 2c carry in a central processing area the processing circuitry and are stacked on the heat drain profiles 5a-d with their soldering holes 14 (see Fig. 2). The soldering holes 14 have sufficient tolerance in shape, orientation and position to the heat drain profiles 5a-d to avoid strain on the assembled processing stages 2a, 2b, 2c. To fixate the processing stages 2a, 2b, 2c and to establish thermal and electrical conductivity the heat drain profiles 5a-d are soldered in the soldering holes 14.

Thermal energy is generated as a by-product of the operational function of the processing circuitry in the central processing area of the processing stages 2a, 2b, 2c. This radial energy is radially transmitted to the periphery where the soldering holes are located. Each processing stage 2a, 2b, 2c has a maximum thermal processing energy (MTPE) that is generated during full stage operation and during a given time unit (TU). The thermal energy causes a rise of the stage temperature, which has to remain with a safety distance 60 (see Fig.3) below a critical level 61 (see Fig.3) under worst conditions. The worst conditions are defined by a high surrounding air temperature 45 and eventual reduction of

the cooling capacity of the heat sink base 1 because of deposited dust that may clog the ribs 16.

The soldering holes 14 are of a hole material with high thermal contact conductivity (TCC) and define with their section length and their height a bridging area. The TCC and the size of the bridging area define a maximum thermal bridging energy (MTBE) that can bridge from one of the processing stages 2a, 2b, 2c onto the heat drain profiles 5a-d during TU and at a given bridging temperature difference (BTD) between the stage hole temperatures 41a-c (see Fig.3) and a local profile temperature. The MTPE together with a safety margin energy is MTBE. The safety margin energy covers eventual corrosion in the bridging areas, which may reduce the TCC.

The first functional stage 3 may carry the lens system as it is known for optical transceivers. The second functional stage 4 features the design elements required for aligning and accessing a cable plug of a fiber optic cable as known to those skilled in the art. Exemplary alignment features for such a cable plug are the alignment pins 6a, 6b. Exemplary access features are the plug slots 7a, 7b where receiving and emitting light beams pass through.

Fig. 2 shows a perspective view of the optical multiplex transceiver as described above with its heat sink base 1 being visible. The heat sink base 1 has a preferably rectangular section hull contour with a number of cooling

ribs 16 being placed between the corner bases 17 that hold the heat drain profiles 5a-d with their base holes 12a-d.

The corner bases 17 have a corner base width 22 where the thermal energy drained from the heat drain profiles 5a-d passes through and onto a heat sink core 18. The heat sink core 18 in the center of the heat sink 1 receives a thermal energy that is drained from the heat drain profiles 5a-d in the corner bases 17 and distributes it evenly to the cooling ribs 16, which increase the air contact surface of the heat sink base 1. The heat sink base 1 is kept in a decoupling distance 19 to the adjacent processing stage 2a to avoid thermal shorting of the designated thermal path and to provide full air contact for the heat sink 1.

15

It is noted that the cooling ribs 16 may be placed at any location of the heat sink base 1.

The metallic materials of the heat drain profiles 5a-d are electrically conductive to allow for electrical power delivery, electrical ground and/or electrical signal transmission between the individual stages. The heat drain profiles 5a-d are preferably utilized to provide a ground and a faraday shield for the optical processing stages 2a, 2b, 2c. The heat drain profiles 5a-d ground thereby the optical processing stages 2a, 2b, 2c the heat sink base 1. The circular arrangement of the heat drain profiles 5a-d provide a faraday shield effect thereby to shield the optoelectronic receiver/emitter structures 24a, 24b (see

Fig. 4) and the supporting electronic circuitry **23** against peripheral electromagnetic noise.

The heat sink base **1** has an extrusion height **20** to provide
5 sufficient mechanical interlocking length with the heat
drain profiles **5a-d** and sufficient surface of the heat sink
1. Extrusion profiles have a minimum wall thickness and
gap width that is limited by the fabrication technique.
Thus a maximum section contour length is defined, which
10 leaves the extrusion height **20** as the only variable factor
to increase the heat sink surface necessary to exchange the
sum thermal energy generated by all processing stages **2a**,
2b, **2c** under worst climatic conditions. As a result, the
extrusion height **20** typically exceeds significantly the
15 main thermal exchange length **32** (see **Fig. 3**) between the
heat drain profiles **5a-d** and the heat sink base **1**. The
reduction of the TCC caused by the optional electrical
insulation layer increases the thermal exchange length **32**
within the extrusion height **20** and the overall cooling
20 performance remains unaltered.

The rectangular design typically used for electronic
circuitry and subsequently the typical election of four
heat drain profiles **5a-d** limits the amount of electrical
25 transmission paths between the individual processing stages
2a, **2b**, **2c**. Optional ball grid arrays **15a**, **15b**
correspondingly placed on all processing stages **2a**, **2b**, **2c**
provide additional electrical transmission paths. **Fig. 2**
shows the optional ball grid arrays **15** only on one side of
30 the processing stage **2a** without contacting an adjacent

processing stage and is shown solely for purposes of visualization. It is appreciated that anybody skilled in the arts may place the optional ball grid arrays **15a**, **15b** between the processing stages **2a**, **2b**, **2c** to establish
5 functioning electrical path between them.

Fig. 3 shows the optical multiplex transceiver as described above in side view together with a corresponding graph that visualizes the temperature relations of the preferred
10 application of the invention. The horizontal axis of the graph corresponds to the dimensions of the optical multiplex transceiver in the main heat drain direction **9a** and the secondary heat drain direction **9b**. The vertical axis of the graph represents temperatures. The values and
15 relations shown in this graph are shown for the sole purpose for visualization without any claim for accuracy. Given is an surrounding air temperature **45** with a maximum level of typically 85 degrees centigrade, which results in a maximum level of the stage peak temperatures **41a-c** for a
20 maximum thermal energy generated in the processing stages **2a-c**. Each of the processing stages **2a-c** has a stage hole temperature **42a-c** at the contact surface of the bridging area of the soldering holes **14**. For purposes of visualization circumferential variations of the stage hole
25 temperature **42a-c** are neglected in **Fig. 3**.

The level differences between the stage peak temperatures **41a-c** and their corresponding stage hole temperatures **42a-c** are defined by the radial thermal conductivity within the
30 processing stages **2a-c**. Optional thermally conductive

layer structures with radial orientation increase the radial conductivity. Electrical leads, which are typically made from copper based materials with good thermal conductivity properties connect the central processing area
5 with the ball grid arrays, and hence serve simultaneously to reduce the radial thermal conductivity of the processing stages 2a-c.

The drain profile temperature curve 43 visualizes the
10 temperature of the heat drain profiles 5a-d at various locations. For the purpose of visualization, radial temperature variations of the heat drain profiles 5a-d are neglected in Fig. 3.

15 In the exemplary visualization of the graph each of the processing stages 2a-c has the same TCC and the same average GBTD between the drain profile temperature curve 43 and the stage hole temperatures 42a-c. As a result, the curve segments 43c, 43e, and right part of 43g are shown in
20 the graph to be parallel and having the bridging decline angle 47a-c. The left part of curve segment 43g is declining towards the first and second functional stages 3, 4, which do not generate heat and thus have a cooling influence on the heat drain profiles 5a-d. As a result,
25 the main heat drain direction 9a is inverted in the peak 48 to the secondary heat drain direction 9b.

The first functional stage 3, which preferably carries the lenses to focus the passing light beams is close to the
30 heat generating processing stage 2c and has a relatively

small surface contact to surrounding air. The lowest temperature 432 of the first functional stage is therefore only insignificantly below the curve segment 43h. The hole temperature 431 of the first functional stage is located
5 between lowest temperature 432 and curve segment 43h at a location dependent on the relation between internal thermal conductivity (ITC) and the thermal bridging conductivity (TBC) in the bridging area.

10 The second functional stage 4 has more surface exposed to the cooling air and is separated by the first functional stage 3 from the next heat producing processing stage 2c. Hence, its lowest temperature 442 and its hole temperature 441 are significantly below the curve segment 43i.

15

Having a constant TCC in all stages and having constant thermal properties of the heat drain profiles 5a-d over their length in the example visualized in Fig. 3, the thermal energy bridges proportional to the bridging
20 temperature difference BTD between the contact surface of the soldering holes 14 and the drain profile surface in the bridging areas. It is appreciated that anybody skilled in the art may vary the TCC between or within each of the processing stages 2a-c and the heat sink base 1. It is also
25 appreciated that anybody skilled in the art may vary the thermal properties, geometric shapes, and numbers of the heat drain profiles 5a-d over their length without diverting from the scope of the invention.

The curve segments 43b, 43d, 43f show the temperature decline with the conduction decline angle 46 in the heat drain profiles 5a-d over the traveling length of the thermal energy. The conduction decline angle 46 is
5 dependent on the material specific thermal conductivity and the size of the section area of the heat drain profiles 5a-d as it is known to those skilled in the art. Since thermal energy is imposed on the heat drain profiles 5a-d at the curve segments 43c, 43e, 43g they have the bridging
10 decline angles 47a-c. For the constant TCC and BTd in the bridging decline angles 47a-c are proportional to the imposed and drained thermal energy.

At the peak 48 the thermal flow changes from the direction
15 towards the heat sink base 1 to the direction towards the first and second functional stages 3, 4. Reducing the TCC of the first and second functional stages moves the peak 48 towards the left end of the processing stage 2c and results in less energy and less thermal load imposed onto the first
20 and second functional stages 3,4.

The heat sink base 1 has a heat sink hole temperature 44 and the heat sink core temperature 44b, which has level discrepancies over its length dependent on the mass of the
25 heat sink core 18. For the purpose of visualization, the heat sink core temperature 44b is defined as constant over the heat drain direction 9. In the exemplary monolithic heat sink base 1 the thermal conductivity between the base holes 12a-d and the heat sink core 18 depends mainly on

the corner base width 22 and is represented by the third decline angle 49.

5 The heat sink base 1 receives the sum thermal energy from all heat generating processing stages 2a-c, except the thermal energy that is transmitted onto the first and second functional stages 3,4 and a certain energy amount that is transmitted to the surrounding air along the thermal path. The heat sink base 1 transmits the thermal
10 energy mainly via convection to the surrounding air. As it is known to those skilled in the art, the thermal exchange energy at TU between heat sink base 1 and the surrounding air is dependent on the size of the air contact surface, the air flow characteristic around the heat sink base 1,
15 the convection temperature difference (CTD) between heat sink temperature 44b and surrounding air temperature 45 and the TCC between surrounding air and air contact surface. It is appreciated that anybody skilled in the art may change the design of the heat sink base 1.

20 The heat drain profiles 5a-d drain the sum thermal energy over the main thermal exchange length 32. The curve segment 43a approaches asymptotically the hole temperature 44 such that the temperature difference in the secondary
25 thermal exchange length 33 is at low level insignificant for thermal energy exchange is.

In the following, the heat transfer of the invention is described against the main heat drain direction 9a since
30 the surrounding air temperature 45 at the very end of the

thermal path defines the profile peak temperature 48 and consequently the stage peak temperatures 41a-c. The base hole temperature 44 is a result of the given surrounding air temperature 45 and depends on it as described above.

5

Between thermal path point 50 and 51 the temperature rises in the heat drain profiles 5a-d according to the curve segment 43a. The higher the temperature difference to the base hole temperature 44, the more thermal energy is drained from the heat drain profiles 5a-d and the steeper the curve segment 43a becomes. Between thermal path point 51 and 52 the temperature rises with the thermal conductivity angle 46, which is defined by the section size and the thermal conductivity of the material of the heat drain profiles 5a-d.

Between thermal path point 52 and 53 the temperature rises with the thermal conductivity angle 47a, which is defined by the thermal energy generated in the processing stage 2a at TU and is imposed over the hole heights 21a on the heat drain profiles 5a-d within. The stage hole temperature 42a and consequently the stage peak temperature 41a rise above the level of curve segment 43c to the point where the BTB is sufficient to drain the generated thermal energy to the heat drain profiles 5a-d.

Between thermal path point 53 and 54 the temperature raises with the thermal conductivity angle 46.

Between thermal path point **54** and **55** the temperature rises with the thermal conductivity angle **47b**, which is defined by the thermal energy generated in the processing stage **2b** at TU and is imposed over the hole heights **21b** on the heat drain profiles **5a-d** within. The stage hole temperature **42b** and consequently the stage peak temperature **41b** rise above the level of curve segment **43c** to the point where the BTD is sufficient to drain the generated thermal energy to the heat drain profiles **5a-d**.

10 Between thermal path point **55** and **56** the temperature rises with the thermal conductivity angle **46**.

Between thermal path point **56** and **57** the temperature rises with the thermal conductivity angle **47c**, which is defined by the thermal energy generated in the processing stage **2c** at TU and is imposed over the hole heights **21c** on the heat drain profiles **5a-d** within. The stage hole temperature **42c** and consequently the stage peak temperature **41c** rise above the level of curve segment **43g** to the point where the BTD is sufficient to drain the generated thermal energy onto the heat drain profiles **5a-d**. At the profile peak temperature **48** the heat drain direction **9a** inverts and flows in secondary heat drain direction **9b** towards first and second functional stages **3, 4** and is drained as described above.

Hence, the temperature increase over the thermal path as described above results in a maximum level of the stage peak temperature **41c**. For a most unfavorable high level of the surrounding air temperature **45**, the sum thermal

conductivity of the thermal path is at a level to have the maximum level of the stage peak temperature **41c** with a minimal safety temperature margin **60** below the a maximum operation temperature **61**.

5

Fig.4 shows the front view of one of the processing stages **2a-c** with superimposed isothermal temperature lines visualizing the lateral temperature distribution. The exemplary processing stage **2** has in its central area an optoelectronic receiver structure **24a**, an optoelectronic emitter structure **24b** and supporting electronic circuitry **23** in immediate surrounding. Electrical conductive leads **25** emanate in radial direction from the supporting electronic circuitry **23** and connect with the ball grid arrays **15a, 15b**. The processing heat generated by the circuitry results in the shown stage peak temperature **41**. The thermal energy that is produced flows radially away and is captured at peripheral ring structure **26** and redirected towards the soldering holes **14**. Over the thermal path in the processing stage **2** the temperature declines according to the local thermal conductivity. The temperature decline is visualized by the isothermal temperature lines **41I-III** and **42I-III** with constant temperature differences. Since the thermal conductivity of the central processing area is low the isothermal temperature lines are closer together. The radial conductive leads **25** increase the thermal conductivity. The peripheral ring structure **26** has a good thermal conductivity, which results in a larger distance between the isothermal temperature lines. The peripheral ring structure **26** has sufficient mass around the soldering

10
15
20
25
30

holes 14 such that the circumference temperature discrepancies along the circumference are kept below a maximum level.

- 5 The circumferential temperature discrepancies result in thermal expansion differences of the heat drain profiles 5a-d, which alter their straightness and impose radial mechanical tensions onto the processing stages 2a-c. The maximum level of the circumferential temperature difference
10 is the level, at which the straightness of the heat drain profiles remains within a predetermined limit.

It is appreciated that the soldering holes 14 may be shaped such that they contact the heat drain profiles 5a-d only on
15 a portion of their circumference and that the heat drain profiles 5a-d may have a noncircular section shape with a cooling feature like for instance cooling ribs.

It is appreciated that the heat drain profiles 5a-d may be
20 connected to each other at a portion or all over their length such that they may form a singular profile with preferably hollow section shape. The stages 2a-c, 3, and 4 may be stacked and aligned there within without diverting from the scope of the invention. Precision alignment
25 features may be utilized between individual optoelectronic processing stages 2a, 2b, 2c to position the optoelectronic processing stages 2a, 2b, 2c with a higher precision than it is provided by the heat drain profiles 5a-d.

It is appreciated that the invention may be utilized for vertical-cavity surface-emitting laser and edge-emitting laser as they are known to those skilled in the art.

- 5 Accordingly, the scope of the invention should be determined by the following claims and their legal equivalents:

1 What is claimed is:

2

3 1. A stack-module multiplex transceiver for transmitting
4 signals between an optical cable end and a connector
5 array of a circuit board, said stack-module multiplex
6 transceiver being stack-assembled on a number of heat
7 drain profiles in parallel orientation to a beam
8 direction defined by said optical cable end and
9 comprising:

10

11 A) a heat drain base holding said number of heat
12 drain profiles;

13 B) at least one processing stage comprising:

14

15 1) an optical communication device;

16 2) a controller circuitry; and

17 3) a number of guiding means for receiving said
18 heat drain profiles.

19

1 2. The stack-module multiplex transceiver of claim
2 1, wherein said heat drain base is a profile
3 extending along said beam direction.

4

1 3. The stack-module multiplex transceiver of claim
2 1, wherein said stack-module multiplex
3 transceiver comprises an optical stage.

4

1 4. The stack-module multiplex transceiver of claim
2 1, wherein said stack-module multiplex
3 transceiver comprises a functional stage.

4

1 5. The stack-module multiplex transceiver of claim
2 1, wherein said stack-module multiplex
3 transceiver comprises a cable alignment stage.

4

1 6. The stack-module multiplex transceiver of claim
2 1, wherein said processing stages have edge
3 castellations.

4

1 7. The stack-module multiplex transceiver of
2 claim 6, wherein said edge castellations are
3 laterally placed on at least one of said
4 processing stages.

5

1 8. The stack-module multiplex transceiver of claim
2 1, wherein said heat drain profiles are in
3 thermal communication with said guiding means.

4

1 9. The stack-module multiplex transceiver of claim
2 1, wherein said guiding means are in electrical
3 communication with said control circuitry.

4

1 10. The stack-module multiplex transceiver of claim
2 1, wherein said processing stages have leads,
3 said leads being electrically and thermally
4 conductive.

5

1 11. The stack-module multiplex transceiver of
2 claim 10, wherein said leads terminate in
3 peripheral ball grid arrays.

4

1 12. A stack-module multiplex transceiver for transmitting
2 signals between an optical cable end and a connector
3 array of a circuit board, said stack-module multiplex
4 transceiver being stack-assembled on a heat drain
5 profile in parallel orientation to a beam direction
6 defined by said optical cable end and comprising:

7

8 A) a heat drain base holding said heat drain
9 profile;

10 B) a number of processing stages, at least one of
11 said number of processing stages comprising:

12

13 1) an optical communication device;

14 2) a controller circuitry; and

15 3) a guiding means for receiving said heat
16 drain profile.

17

1 13. The stack-module multiplex transceiver of claim
2 12, wherein said heat drain profile has a cooling
3 feature.

4

1 14. A method for simultaneous aligning and cooling of
2 processing stages within a stack assembly, said method
3 comprising the following steps:

4

5 A) binding and aligning heat drain profiles parallel
6 in a heat sink base;

- 7 B) shaping and placing heat transfer areas of said
8 processing stages correspondingly with section
9 contours of said drain profiles;
10 C) thermally connecting a processing area of said
11 processing stages with said heat transfer areas;
12 D) stacking said processing stages with said heat
13 transfer areas on said heat drain profiles and
14 contacting said heat transfer areas with said
15 heat drain profiles; and
16 E) transmitting a processing heat from said
17 processing areas to said heat transfer areas and
18 onto said heat drain profiles, whereby said
19 processing heat is drained from said drain
20 profiles into said heat sink base.

21

- 1 15. The method of claim 14, wherein said heat drain
2 profiles are electrically conductive.

3

- 1 16. The method of claim 15, wherein said heat
2 transfer areas communicate electrically with
3 said processing areas and said heat drain
4 profiles.

5

- 1 17. The method of claim 15, wherein said heat
2 drain profiles communicate electrically with
3 said heat sink base.

4

- 1 18. The method of claim 14, wherein said processing
2 areas process optical signals.

3

1 19. The method of claim 14, wherein said processing
2 areas process electrical signals.

3

1 20. The method of claim 14, wherein said processing
2 areas receive a signal light beam.

3

1 21. The method of claim 20, wherein said signal
2 light beam has a beam direction parallel to
3 said heat drain profiles.

4

1 22. A method for simultaneous aligning and cooling of
2 processing stages within a stack assembly, said method
3 comprising the following steps:

4

5 A) binding and aligning a heat drain profile
6 parallel in a heat sink base, whereby said heat
7 drain profile provides an alignment feature for
8 orientation and position for said processing
9 stage;

10 B) shaping and placing heat transfer areas of said
11 processing stages correspondingly with section
12 contours of said drain profiles;

13 C) thermally connecting conductive a processing area
14 of said processing stages with said heat transfer
15 areas;

16 D) stacking said processing stages with said heat
17 transfer areas on said heat drain profiles and
18 contacting said heat transfer areas with said
19 heat drain profiles; and

20 E) transmitting a processing heat from said
21 processing areas to said heat transfer areas and
22 onto said heat drain profiles, whereby said
23 processing heat is drained from said drain
24 profiles into said heat sink base.

25

1 23. The method of claim 22, whereby said heat drain
2 profile has a cooling feature.

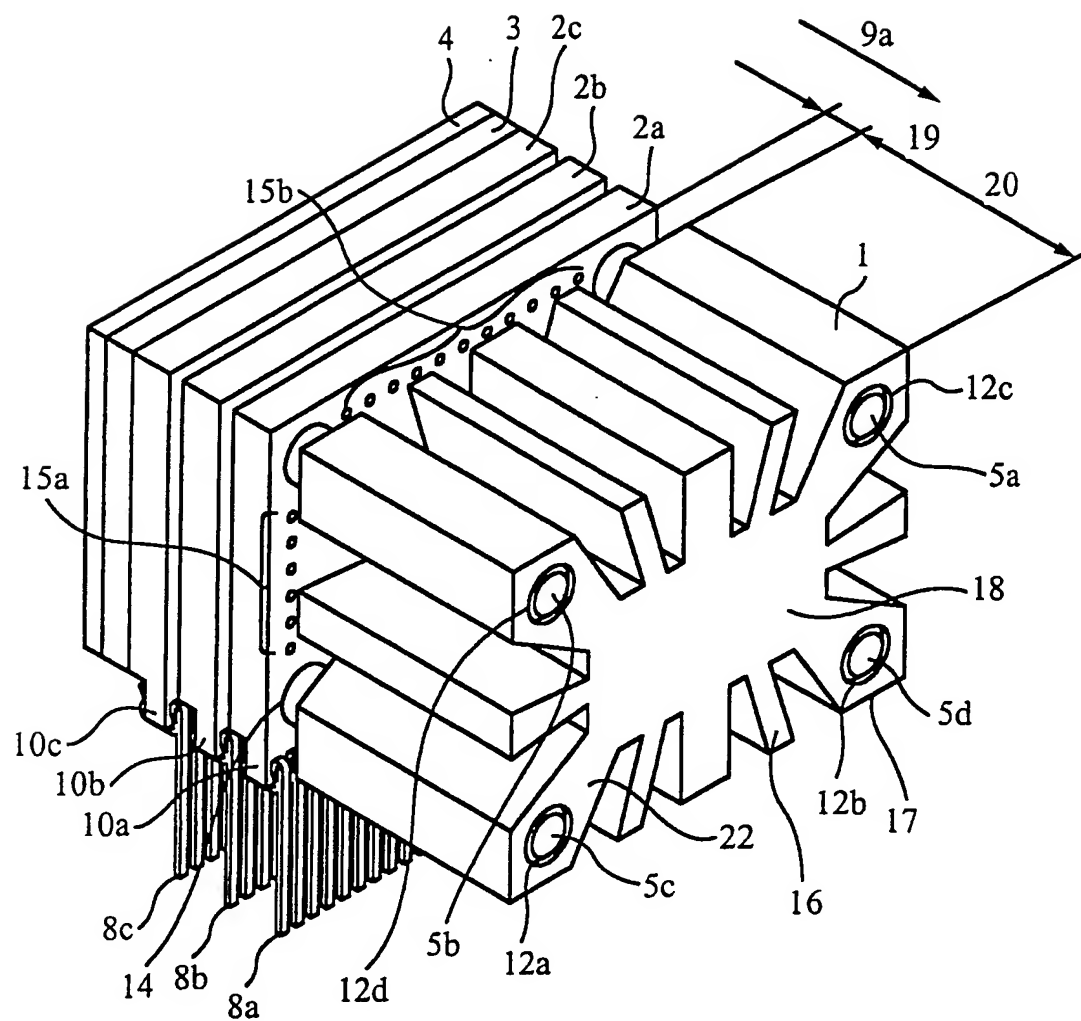


FIG. 2

3/4

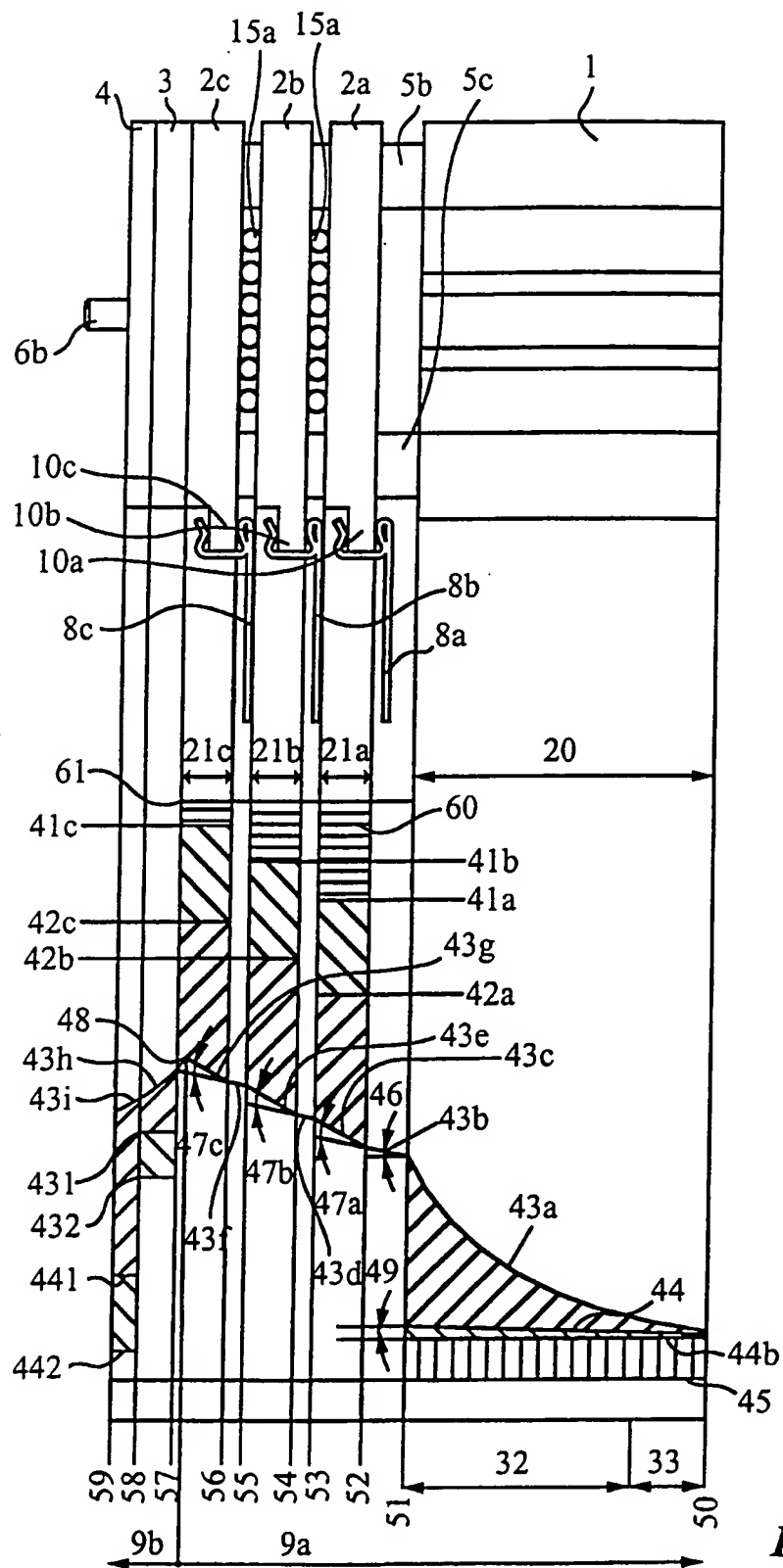
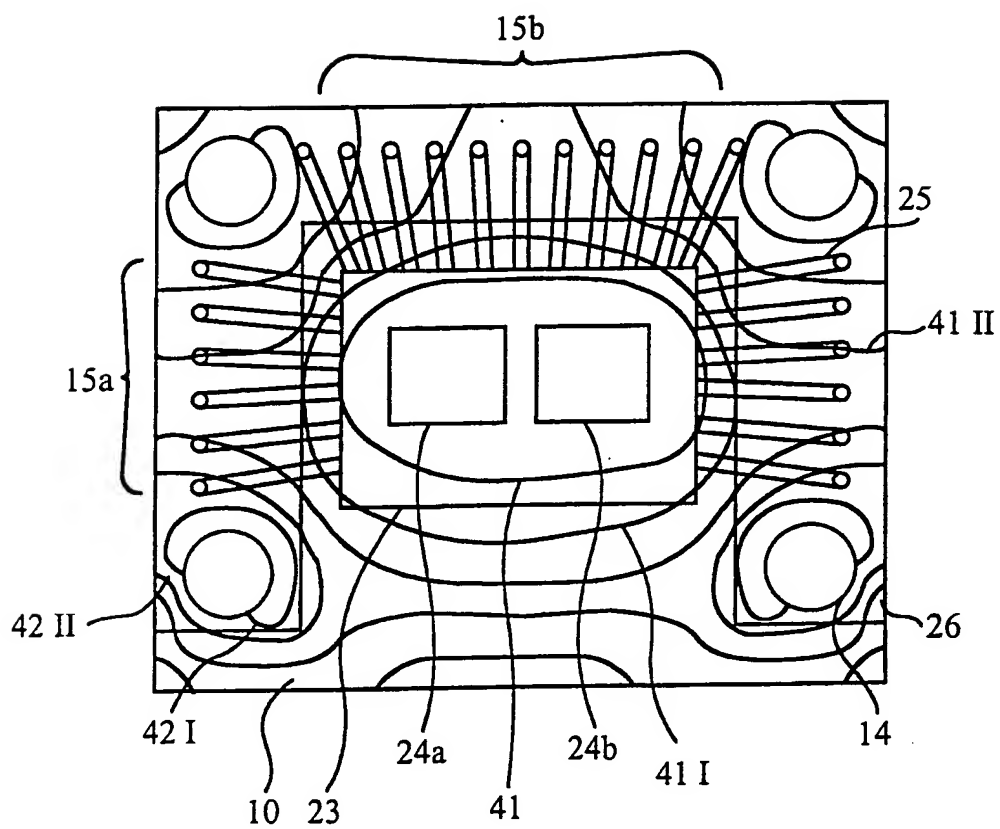


FIG. 3

4/4

**FIG. 4**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/28017

A. CLASSIFICATION OF SUBJECT MATTER IPC(7) : Please See Extra Sheet. US CL : 324/760; 359/152, 143; 361/382; 361/386; 385/92; 257/879, 80, 86 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 324/760; 359/152, 143; 361/382; 361/386; 385/92; Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) USPAT		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 6,097,521 A (ALTHAUS et al) 01 August 2000, col. 10, lines 4-67.	1, 4, 12
X	US 5,999,295 A (VOWELL et al) 07 December 1999, col. 1, lines 39-49, col. 6, lines 64-67-col. 7, lines 1-15.	1
A,P	US 6,024,500 A (WOLF) 15 February 2000, lines 1, lines 55-67 - col. 2, lines 1-25, lines 40-67.	1-3, 5, 9, 10, 12, 15-20
X,P	US 6,072,613 A (HENNINGSSON et al) 06 June 2000, col. 1, lines 31-67 - col. 3, lines 1-67	3, 9, 18-21
A	US 5,731,709 A (PASTORE et al) 24 March 1998, col. 9, lines 10-67 - col. 10, lines 1-47.	6, 7, 11, 13, 14, 22, 23
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document published on or after the international filing date *L* document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art *G* document member of the same patent family	
Date of the actual completion of the international search 08 JANUARY 2001		Date of mailing of the international search report 08 MAR 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3988		Authorized officer LESLIE PASCAL <i>Karen L. Ward</i> Telephone No. (703) 305-4700

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/28017

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,706,164 A (L'HENAFF et al) 10 November 1987, col. 1, lines 61-68 - col. 1, lines 1-52.	1, 2, 8, 12-17, 21, 22, 23
A	US 4,701,829 A (BRICAUD et al) 20 October 1987, abstract.	8, 10, 14, 17, 22
X,P	US 5,994,720 A (SNYMAN et al) 30 November 1999, col. 10, lines 14-50, Fig. 15	1, 3, 4, 9, 10, 19
X,P	US 6,111, 271 A (SNYMAN et al) 29 August 200, col. 1, lines 15-24, abstract.	1, 3, 4, 9, 10, 19
X	US 5,808,336 A (MIYAWAKI) 15 September 1998, col. 18, lines 31-58	2, 10, 12, 13, 15, 16, 19

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/28017

A. CLASSIFICATION OF SUBJECT MATTER:

IPC (7):

G01R 31/02; H04B 10/02, 10/00; H02B 1/00; H05K 7/20; G02B 6/36; HO1L 29/788, 33/00

This Page is inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☒ BLURED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLORED OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REPERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images
problems checked, please do not report the
problems to the IFW Image Problem Mailbox**